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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

EMF2016 ELECTROMAGNETIC THEORY (All Sections / Groups)

22 OCTOBER 2019
2.30 P.M – 4.30 P.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 10 pages including this cover page with 4 questions only. Common constants for air are listed on Page 5.
2. Attempt all four questions. All questions carry equal marks and the distribution of marks for each question is given.
3. Please print all your answers in the answer booklet provided.
4. Please tie and submit worked Smith charts together with the answer booklet.

Question 1

A $100\ \Omega$ air-filled coaxial line is terminated by an antenna with an impedance $(50 + j75)\ \Omega$. The source is operating at 10 GHz.

- (a) Without using Smith chart, compute the following parameters.
- (i) The voltage reflection coefficient at the antenna. [3 marks]
 - (ii) The location of the nearest voltage maximum from the load. [4 marks]
 - (iii) The standing wave ratio on the coaxial line. [3 marks]
- (b) Using Smith charts, design a single stub tuner to match the antenna to the coaxial line by finding:
- (i) the shortest electrical distance between the stub and the antenna [8 marks]
 - (ii) the stub electrical length. Use a $100\ \Omega$ shunt short-circuited stub. [7 marks]

(Smith charts are provided at the end of question paper. **You need to submit the worked Smith charts.** Write all markings and labels clearly. Detach them from the question paper and tie them to your answer booklet.)

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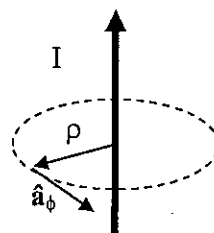
Question 2

- (a) Define Lenz's Law in electromagnetic field. [3 marks]
- (b) Write the Maxwell's equations in integral form and differential form. [6 Marks]
- (c) Using Ampere's law, show that the magnetic flux density developed (in a homogeneous and isotropic medium) around an infinitely long straight wire carrying a current I is given by:

$$\underline{\mathbf{B}} = \hat{\mathbf{a}}_{\phi} \frac{\mu I}{2\pi\rho}$$

where μ is the medium permeability, ρ is the radial distance from the long wire, and $\hat{\mathbf{a}}_{\phi}$ is the unit tangential vector as defined in Figure Q2(c).

[7 marks]

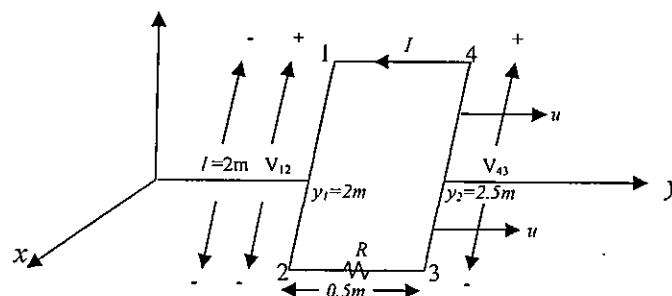
**Figure Q2(c)**

- (d) Figure Q2(d) shows a rectangular loop which is situated in the x - y plane and moves away from the origin at a velocity $u = \hat{y}4$ (m/s) in a magnetic field given by:

$$\underline{\mathbf{B}}(y) = \hat{\mathbf{z}}0.25e^{-0.1y}$$

If $R = 1 \Omega$, find the current I at the instant that the loop sides are at $y_1 = 2$ m and $y_2 = 2.5$ m. The loop resistance may be ignored.

[9 marks]

**Figure Q2(d)**

Continued ...

Question 3

- (a) The magnetic field of a uniform plane wave propagating in a lossless, non-magnetic material is given by:

$$\underline{H} = \hat{y} 25 \cos(2\pi \times 10^7 t - 0.3x) \quad (\text{mA/m}).$$

Determine the followings:

- (i) the direction of wave propagation, [1 mark]
- (ii) the phase velocity, u_p , [2 marks]
- (iii) the wavelength, λ , [2 marks]
- (iv) the dielectric constant, ϵ_r , [2 marks]
- (v) the intrinsic impedance, η , [2 marks]
- (vi) the time-domain expression of the electric field, $\underline{E}$. [3 marks]

- (b) A 30 MHz plane wave in air (medium 1) impinges at normal incidence on a flat surface of a second dielectric medium (medium 2) with $\sigma = 0$, $\mu = \mu_0$ and $\epsilon = 2\epsilon_0$. If the incident electric field is given by:

$$\underline{E}_i = \hat{y} 10 \cos(\omega t - \beta_1 z) \quad (\text{V/m}),$$

Determine the followings:

- (i) the phase constants in both mediums, β_1 and β_2 [4 marks]
- (ii) the reflection coefficient. [4 marks]
- (iii) the time domain expressions of the reflected and transmitted electric fields, $\underline{E}_r$ and $\underline{E}_t$. [5 marks]

Continued ...

Question 4

- (a) Compare the propagation modes in coaxial cable transmission line with the propagation modes in hollow rectangular waveguides. State the modes in each case and describe the property of the modes.

[5 marks]

- (b) A rectangular waveguide with dimensions $a = 3$ cm, and $b = 1$ cm is filled with a medium with $\sigma = 0$, $\varepsilon = 9\varepsilon_0$, and $\mu = \mu_0$.

- (i) Determine the dominant mode cutoff frequency.

[4 marks]

- (ii) If the operating frequency is below 5 GHz, will TM_{21} mode propagate in the waveguide? Give your justification.

[4 marks]

- (c) The electric field component of the wave propagating in an air-filled rectangular waveguide is given by

$$E_z = 10 \sin\left(\frac{2\pi x}{a}\right) \sin\left(\frac{\pi y}{b}\right) \cos(2\pi \times 10^9 t - 19z) \text{ V/m}.$$

The waveguide dimensions is a (m) $\times$ b (m). Determine the following:

- (i) The phase constant.

[1 mark]

- (ii) The operating frequency.

[1 mark]

- (iii) The unbounded phase constant.

[2 marks]

- (iv) The propagation mode.

[2 marks]

- (v) The cutoff frequency.

[3 marks]

- (vi) The wave impedance.

[3 marks]

Common constants for air

Speed of light, $c =$	3×10^8 m/s
Permittivity, $\varepsilon_0 =$	8.854×10^{-12} F/m
Permeability, $\mu_0 =$	$4\pi \times 10^{-7}$ H/m
Intrinsic impedance, $\eta_0 =$	377Ω

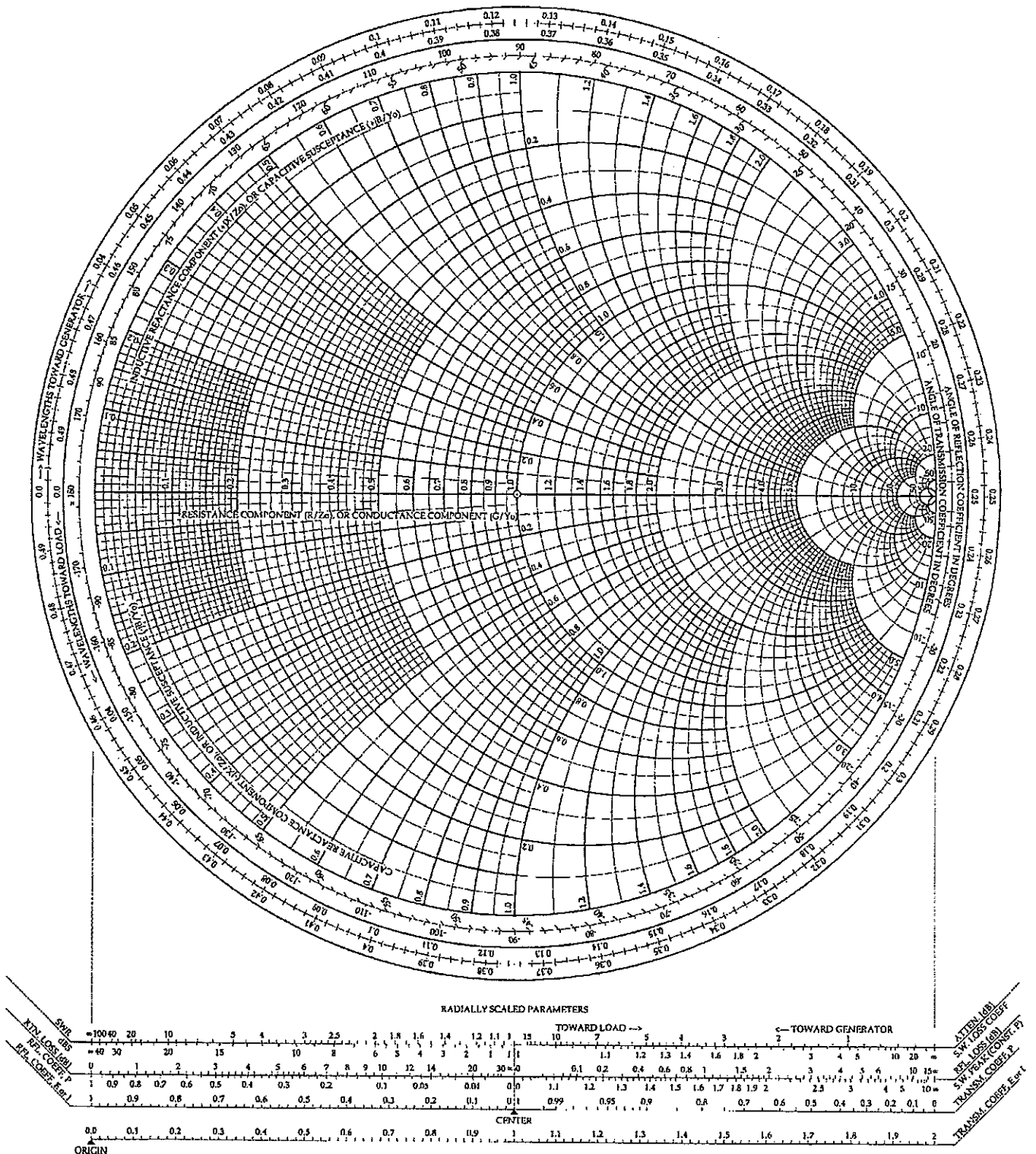
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The Complete Smith Chart

Black Magic Design

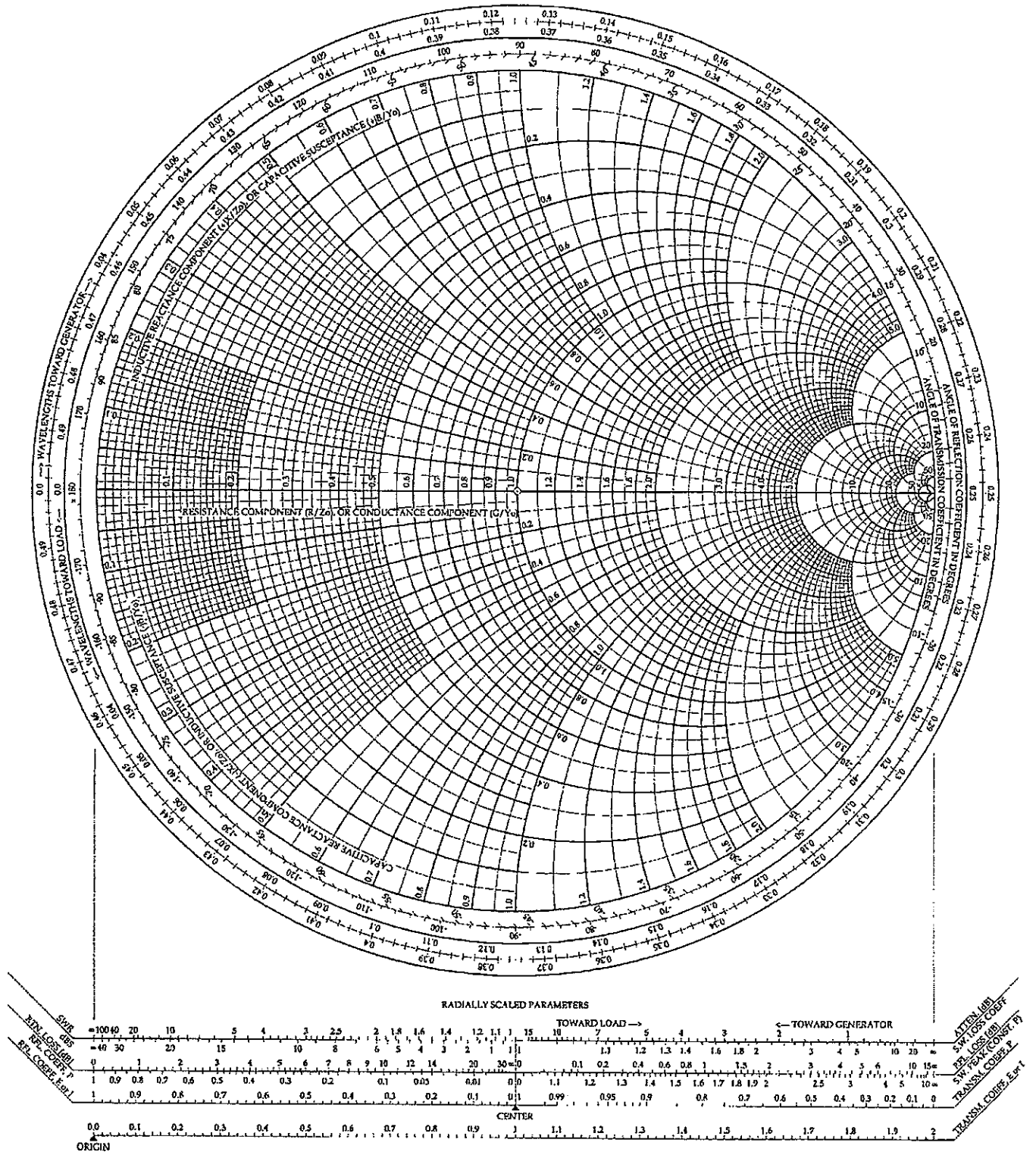


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The Complete Smith Chart

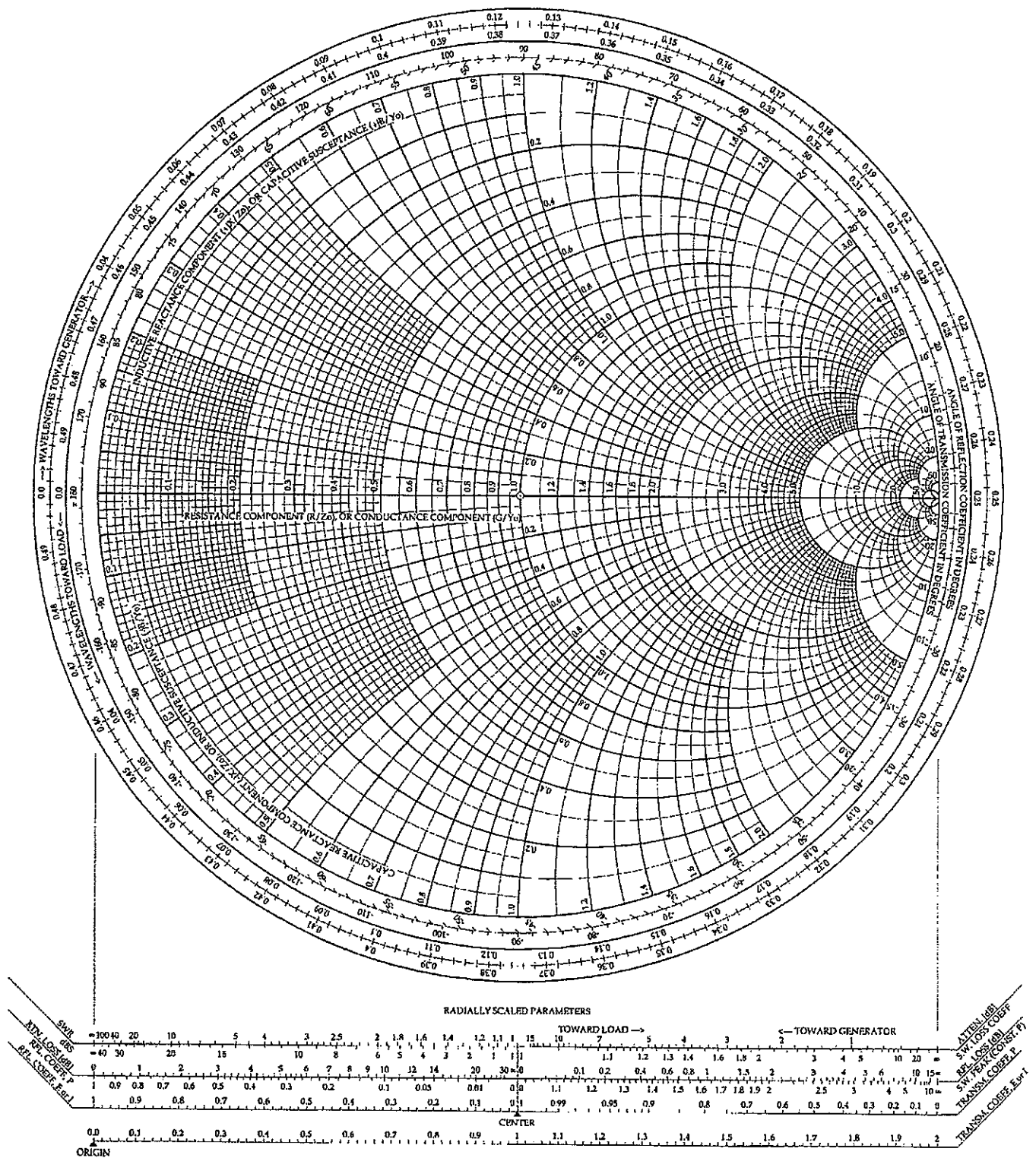
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The Complete Smith Chart

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